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ABSTRACT

An analysis of the gap between educational productivity and technological advancement concludes that American education's dismal productivity level is partly due to the lack of investment in research and development. Successful school restructuring must include the following innovations: site-based management; public school choice; competitive markets; realistic accounting; meaningful incentive programs; and valid evaluation processes. An initiative to close the gap is proposed, in which U.S. institutions and training facilities allocate at least one percent of their budgets for a research and development fund to be managed by a new National Institution for Learning Technology. (LMI)

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Hudson Institute **Briefing Paper**

November 28, 1989 No. 111

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Closing Education's Technology Gap

by Lewis J. Perelman

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[SUMMARY: Viewed as an economic sector, education has the worst productivity record of any major U.S. industry. Part of the reason is that education invests a hundred to a thousand times less in research and development than other, information-based businesses. To close the gap, U.S. education and training institutions should set aside at least 1% of their budgets for an R&D fund to be managed by a new National Institute for Learning Technology.]

Education costs too much. At the same time that the learning enterprise--the vast business of education, training, and learning activities--is becoming more crucial to an information age society,[1] the spiralling cost of conventional education's dubious output is becoming a millstone around the neck of the entire national economy. Education's productivity crisis lies at the heart of our country's overall human capital predicament.

Emerging initiatives to not merely reform but to "restructure" the nation's educational enterprise in radical ways[2] will be essential to undoing education's productivity malaise. These structural changes--opening public schools to choice and competition, cutting centralized bureaucracy and red tape, holding education and training accountable for actual knowledge and skill gained by students, and revising employment practices to reward competence and flexibility--will finally create an environment where instructional efficiency matters.

But the combination of modern technological and organizational innovations that has enabled productivity to soar in other industries will not occur even in a restructured educational system unless education makes an investment in research and development comparable to other economic sectors. The shocking truth is that, compared to any other major industry, American education's investment in research and innovation is almost nonexistent.

Advocates of restructuring education have tended to overlook the magnitude and importance of education's R&D gap. Closing that gap must be made a top priority item on the restructuring agenda.

Education's productivity crisis

A four-year study by the U.S. Congress' Office of Technology Assessment[3] concluded that the key obstacle thwarting America's shift to an information age economy is the egregiously poor productivity of the education sector. In particular, OTA found that education is tied (with social work) as the most labor-intensive business in the economy, with labor costs equal to 93% of output value, compared to 54% for all private business.

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Education's productivity is not only poor but declining. Since 1950, the real dollar (inflation-adjusted) cost of elementary/secondary (K-12) education in the United States has quadrupled! College is no better bargain: The price tag for higher education doubled in the last decade as costs grew much faster than inflation.

Costs zooming upward, enrollments staying the same or declining, and the quality of the output of schools and colleges either staying as good (according to their fans) or deteriorating (according to their critics) altogether mean that educational productivity--in terms of the ratio of effectiveness to cost--has been going sharply downhill.

The immediate cause of this dreary performance is education's gross lack of investment in technology. OTA's study revealed that education has by far the lowest level of capital investment (another name for "buying technology") of any major industry: only about $1,000 per employee. The average for the U.S. economy as a whole is about $50,000 of capital investment per job. Some high-tech industries invest $300,000 or more in technology for each worker. Even other, relatively labor-intensive, "service" businesses provide at least $7,000 to $20,000 worth of equipment and facilities for each employee.

This is a good place to call attention to a unique characteristic of the education industry, or learning enterprise, that sets it apart from all other businesses, and that makes the above and other unflattering comparisons even worse. That is: **Education is the only business where the consumer does the essential work.** To the extent that learning is education's essential (though not only) business, it's clear that the productivity of the student or learner--not teachers or administrators--is what ultimately counts.

If we count the student, rather than the paid staff, as the "worker" to be compared to workers in other sectors, education's productivity/technology gap looms even larger. Thus, the public schools' niggling capital investment of $1,000 per employee becomes a pathetic $100 per worker if worker means student. As a matter of fact, while the average U.S. public school budget now comes to about $5,000 per student annually, the typical school district expends only about $100 to $200 of that exorbitant sum on materials and tools for each student to use directly for learning.

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In a world where life cycles of product and production technology now are measured in months rather than decades, scanty capital investment inevitably leads to creaking technological backwardness. So we should be dismayed but unsurprised to observe that--in the midst of a global information revolution--the instructional technology available to most students, most of the time, in most American schools and colleges today ranges from 100 to 1,000 years old. While the power of information technology has been leaping upward by factors of 10 every few years since the 1950s, a report a few years ago by the late Ithiel Pool of MIT found that classroom instruction was the only one of some two dozen communications media studied whose productivity sharply declined during the past two decades.

Had the power of educational technology (not in some laboratory but in common use) grown at the same pace over the last four decades as the power of computer technology, a high school or college diploma--which still take 12 and 4 years respectively to produce, at an average cost for either of about $60,000--could be produced in less than ten minutes for about five cents!

The point is not so much that we should expect instant education for a nickel tomorrow, but that at least we should expect the education industry to make some meaningful technological progress in the same direction--forward--as the rest of the economy. This comparison also emphasizes that the technological gap between the school environment and the "real world" is growing so wide, so fast that the educational experience is at risk of becoming not merely unproductive but utterly irrelevant to normal human existence.

The R&D gap

Compared to any other part of the modern economy, the minuscule share of the education industry's vast financial resources invested in research and development is shocking. While the federal government pays less than 9% of the national bill for formal education (school and college), it pays for most of the educational research. Depending on what one counts as "R&D," the federal Education Department spent between $136 million and $388 million on some kind of research in the 1989 fiscal year. Only about a million dollars of this was devoted to development of advanced instructional technology. Most of the research on high-tech teaching and learning is financed by the Defense Department, to the tune of about $200 million annually. The National Science Foundation also allocates about $15 million a year to research on innovative instruction for science and mathematics.

These hundreds of millions of dollars may sound like a lot of money for research until one considers the scale of the nation's learning enterprise. The education and training sector is America's largest information industry and, depending on what is counted, may be simply the country's biggest business. Formal instruction provided by schools, colleges, and corporate and military training departments is about a $400 billion a year industry; OTA estimates it employs around 10% of the U.S. workforce. When on-the-job training and other less visible but no less economically significant forms of teaching and learning are included, the learning enterprise is over a $500 billion business, and may even equal the $600 billion health care industry (generally viewed as the biggest).

By OTA's accounting, the education sector's investment in R&D comes to only 0.025% of its annual revenues. Even if demonstration projects, program evaluations, and other activities plausibly considered "research" are included, education's R&D spending still is less than 0.1% of revenues.

In contrast, R&D accounts for 2.5% of the entire U.S. gross national product. The average American business firm invests 2% of sales in R&D. But in high-tech, information-based businesses--the kind of business education ought to be but isn't--companies commonly plow 7% to 30% of their sales into R&D. For instance, in *Business Week*'s latest "R&D Scoreboard" the five top-rated companies in the computer software and services sector (the fastest growing segment of today's computer industry) spent 26.9%, 17.2%, 17.9%, 16.1%, and 28.6% of their revenues on R&D.

But *Business Week*'s recent research revealed that it is the amount of R&D investment **per employee** that is the most powerful predictor of business success. By that standard, the magnitude of the education sector's failure to invest in innovation is magnified because education, being so labor intensive, dilutes its already piddling R&D expenditures over a relatively larger workforce than other businesses.

For the formal education sector (kindergarten through university), R&D spending per employee is less than $50 a year. Now consider what each of those leading companies in the computer software and services business spend annually on R&D per employee: $42,622; $36,207; $33,535; $30,389; and $30,264.[5] The composite figure for all the companies in all the industries rated by *Business Week* is $5,042 of annual R&D investment per employee.[6]

As dismal as $50 a year for education's per-employee R&D investment appears, it's instructive again to recall that the student is the "worker" whose productivity most matters in the education business. So the education sector's annual R&D investment per worker realistically is something less than $5--**a thousand times less** than the norm for other major industries, and **ten thousand times less** than the amount spent by the most competitive U.S. firms in high-tech, information businesses.

The innovation gap

Clearly, a bold initiative is urgently needed to close education's disastrous R&D gap. But before getting to specific proposals to solve that problem, it's essential to recognize that merely adding dollars to the educational research budget will not, by itself, lead to more innovation or greater productivity in the nation's schools and colleges.

The failure to effectively exploit the instructional power of the computer is just one notable illustration of educational institutions' capacity to resist change. A decade and a half into the "desktop computer" revolution, 40 million personal computers are in use in the United States. Computers called "computers" are in some 20 million American homes. But nearly 30 million U.S. homes have Nintendo "game" units--computer terminals masquerading as toys.

In contrast, another OTA report[7] found that U.S. schools have spent a total of about $2 billion on instructional computers over a period of ten years--that's only a tenth of what the rest of America spends on personal computers **every year**. A recent survey by Henry Jay Becker of Johns Hopkins University determined that there are about two million instructional computers in K-12 schools, only about one for every 20 students on average.[8] Many of the computers counted as "present" in schools are old, obsolete, or simply locked away, unused. While experts have concluded that, ideally, all students should get to use instructional computers for about a third of their time in school, or 10 hours a week, the OTA report estimated that students typically get to use computers in U.S. schools only about one hour a week.

There is little mystery about the broad reasons for the failure of schools and colleges to adopt computers and other technological innovations or about what needs to be done, in general, to remedy these institutions' resistance to progress. The key reasons for the lack of adoption of productive technological innovations in U.S. pre-college education lie in the combination of incentives and disincentives common to government-owned, bureaucratically administered, monopolistic enterprises.

In essence, the public school is America's collective farm. Innovation and productivity are lacking in American education for basically the same reasons they are scarce in Soviet agriculture: absence of competitive, market forces.

The public school normally provides, at best, no incentive--other than altruism or curiosity--for practitioners to adopt innovations. A teacher I interviewed for a recent study of the use of computers in public schools put it succinctly: "Why should I do anything different next year from what I did last year?" In fact, scarcely any schools, even those that aspire to be progressive, offer any substantive reward, or even opportunity, for professional staff to adopt productive tools.

At worst, and commonly, the typical school environment is pregnant with disincentives for innovation which, over a period of a half century or more, have proven highly effective in preventing or reversing technological change in education.

For instance, journalists and other education analysts commonly cite lack of teacher training as a barrier to adoption of instructional computers. Yet training, by itself, cannot overcome bureaucratic disincentives. As Bella Rosenberg of the American Federation of Teachers states bluntly, and correctly: "Teacher training is no substitute for restructuring education." Indeed, training may even prove counterproductive.

The Houston Independent School District, for example, used to provide an intensive, 300-hour teacher training course in the effective use of instructional technology.[9] Yet graduates of the program--the most innovative and technically proficient teachers in the district--who practiced what they had learned actually got negative grades on a state-imposed teacher evaluation instrument that values "teaching" according to the ability to stand in front of a blackboard and talk, rather than the ability, or even willingness, to employ modern, student-centered tools. Staff in the district report that many of the best-trained teachers left the system for jobs where their skills are in demand and rewarded.

The education sector's annual R&D investment per worker realistically is something less than $5--*a thousand times less* than the norm for other major industries, and *ten thousand times less* than the amount spent by the most competitive U.S. firms in high-tech, information businesses.

Despite apparent institutional differences, the barriers and disincentives for innovation in higher education are broadly similar to and equally effective as those that hobble K-12 schools. The list of such obstacles could be extended indefinitely. But the vast majority stem from the bureaucratic structure of the formal education system, not, as some "experts" claim, from inadequate technology or lack of government subsidies.

In contrast to the situation in schools and colleges, demand for computer-based instruction is strong in the unregulated and unsubsidized market for employer-provided education. It is estimated that some 30% of the more than $50 billion employers invest annually in employee training is spent on computer-based instructional systems--that is over seven times more in one year than public schools have spent on instructional computers in the last ten years! Or, to look at the same data from another

angle, **employer-provided education invests a 300 times larger share of its total budget in computer-based instruction than public education does.**

The failure to consider the total market for instructional computing and other advanced technology beyond schools commonly distorts published reports of educational technology's lack of progress.[10] Contrary to what many reports imply, the problem is not that instructional computers don't work well enough, or that they are not affordable, or that educators won't use them. The truth is that computer-based and other high-tech instructional tools are being produced, sold, and used successfully and extensively **outside of schools.**

The key difference is that competition makes corporate and military trainers accountable for costs and results. And the principal reason for the almost total lack of investment in productivity-enhancing technological innovation, and for the record of steadily declining productivity in formal education, is the inherent absence of competitive, market incentives in the bureaucratic structure of the U.S. educational system.

History argues that neither the abundance of current information technology nor further research and invention of even more exotic tools for teaching and learning will, by themselves, have much impact on the near-static pace of innovation in education. Pocket calculators have been ubiquitous for some two decades, yet their common use in pre-college education is still sedulously resisted. Television has been around for half a century yet its educational use remains largely trivial. The telephone is a century-old technology; yet hardly any school teachers in America have their own office telephones or even ready access to one.

An illuminating study by Douglas Ellson[11] unveiled 125 instructional technologies and methods that, according to published research reports, have been proved capable of at least doubling the productivity of teaching. Yet Ellson observed that the use of these productive tools is virtually unknown in U.S. schools and colleges. Over 20 years of research shows that computer-assisted instruction, properly employed, can produce at least 30% more learning in 40% less time at 30% less cost than traditional classroom teaching. The cost to the U.S. economy of education's failure to adopt these kinds of proven, on-the-shelf teaching technology on a large scale may be as much as $100 billion a year.

Continual attempts to inject technological innovation into American schools and colleges through subsidized experimental, pilot, and demonstration projects or top-down bureaucratic mandates have failed as thoroughly as similar initiatives in the Soviet state agricultural system. In contrast, American agriculture has become the most productive in the world because adoption of technological innovation has been motivated by the competitive forces experienced by independent, market-driven enterprises.

The lesson in this is that the massive increase in educational R&D the country desperately needs will not pay off in actual, productive innovation in American schools without a solid dose of *perestroika.* That is, public schools will remain technologically backward until they are forced to compete to attract customers (students) who control the revenues the schools earn. And colleges will continue to eschew efficient instructional technology until instruction is unshackled from the priority of faculty research, productivity takes precedence over selectivity, and institutions are made to compete to generate real learning, not just elite credentials.

On the other hand, the agenda of educational restructuring that has recently evolved from growing disillusion with conventional "reforms" will bear little fruit unless a vastly expanded share of education's resources is committed to the research that is the wellspring of progress and productivity.

A solution to the R&D gap

To start closing the education industry's yawning R&D gap, I propose the following major initiative that we can call the "Hundred-By-One Plan." These are its main provisions:

1. Get every education and training institution, organization, and program in the United States to set aside at least 1% of its gross revenues for investment in research and development.

One percent of revenues for R&D is a painfully modest goal--only half the average R&D spending for U.S. businesses, and far less than is typical in high-tech industries--but it's still at least ten times more than what education now spends. With education and training budgets commonly growing by 5-10% a year, it's hard to imagine that any institution could plausibly argue that taking 1% of its budget away from current operations could cause serious damage. Even greater R&D investment would be welcome, of course, but this minimal amount would get the ball rolling.

2. The goal of this new investment in educational innovation should be to achieve a 100% increase (a doubling) in the productivity of U.S. education and training by a certain date, say, 1996 or 1998.

This is the meaning of a "Hundred (percent growth in productivity) By One (percent investment in R&D)." The specific goal is subject to discussion; as noted above, doubling teaching productivity is a rather modest goal that can be achieved with on-the-shelf technology, without any new invention. The important thing is to have a goal clearly defined in terms of the benefits of R&D, not just the amount spent on R&D. This will help remind institutions, policymakers, and taxpayers that dollars allocated to R&D are not a loss to the budget, but will be returned many times over in greater productivity.

3. These funds will be pooled in a common fund administered by a National Institute for Learning Technology. Contributors will be members of the Institute.

The main reasons for having a single Institute are administrative efficiency, and to achieve "critical mass" or economies of scale in research projects. But the Institute need not and most likely will not be localized in one building or campus. Rather, most of its research operations would be highly decentralized. The National Institute might well be formed most expeditiously as a network or consortium of individual state institutes. The specific form of organization and management will be determined by the Institute's members and directors.

An important reason for having the institutions put up the R&D money through the 1% setaside--rather than rely on subsidies or contributions from others--is that it will increase their motivation to actually adopt innovations. Institutions that have invested their own money in research are likely to be more interested in actually using what they've paid for. One reason that educational institutions have rarely adopted productive innovations demonstrated by research paid for by outsiders is that the institutions have nothing at stake.

By the way, this proposal is not saying that all educational R&D would or should be controlled by the National Institute. If individual states, or school districts, or institutions choose to invest another 5% or 10% or 20% of their budgets in R&D locally or through other consortia, so much the better. The Institute is proposed to assure that--at the least--there is a solid core and critical mass of R&D to serve the nation's learning enterprise.

4. All "professional" staff of the contributing institutions will automatically become voting Associates of the Institute. Associates will elect the Directors, who will determine the priorities for investing the Institute's funds in research and innovation.

Equal in importance to the financial ownership of innovation is the psychological "ownership" that comes with participating actively in the processes of discovery and invention. Thus, the "Associate" membership of education/training professionals in the Institute is a crucial part of the Plan. As we know from both the theory and practice of "sociotechnical systems design" (STS) in factory and office automation, the most productive technological innovations are those developed through the active engagement of both customers and front-line production workers--the primary consumers and producers.

5. Contributing member institutions might be given some preference in the awarding of Institute grants and contracts, to enhance the benefit of membership.

Receiving research grants should not become an entitlement of membership, or the whole benefit of critical mass in pooling funds would be lost. But, on the other hand, there needs to be some unique advantage of Institute membership to cope with the "freeloader" problem inherent in all R&D programs--that is, that those who do not pay for R&D can get most or all of the benefits of research paid for by others.

One way to deal with freeloaders is to limit communication of research results to members, rather than publishing them openly. But such inhibitions generally undermine the R&D process by reducing critical feedback and curtailing potential applications.

Another possible solution to the freeloader problem, of course, would be for government to compel eligible institutions, by statute or regulation, to set aside a share of their budgets to the R&D fund. But such an arrangement would risk aborting many of the benefits of voluntary association: flexibility, quick response, and freedom from political manipulation and bureaucratic red tape. Public and private educational institutions at least ought to have the opportunity to support a national R&D initiative voluntarily before mandates are considered. The experience of institutions such as the Electric Power Research Institute or the part of the old Bell Laboratories that now is known as Bellcore[12] shows that voluntary, collaborative R&D organizations can be viable and productive.

6. Since K-12 staff would tend to outnumber higher education and training professionals among Institute Associates,[13] some provision might be needed to assure a balance of investment among educational needs.

For instance, childhood education could be limited to no more than 50% of the total Institute budget. Some such limitation is desirable not only to attract non-school organizations and professionals but also because the nation's education budget and policies currently are unconscionably neglectful of adult, lifelong,

and non-school learning needs. The 40 million or so American adults who need basic education generally get only about one dollar of investment for every thousand dollars spent on children's education.

What kinds of research and development would the Institute carry out? The specific agenda would be defined by the board and members, but many of the key topics are easy to discern now. Basic research on how brains and artificial systems think and learn, and the application of such research to the development of teaching and learning systems clearly are high priority subjects. Group learning processes and the interaction between human and nonhuman learning systems need more study.

Measurement is an unglamorous but absolutely essential field that needs far more R&D investment if the learning enterprise is to become as innovative and productive as other information industries. Indeed, at present we have only the vaguest idea what "productivity" in education and training means, much less what it is in particular settings. While the groundswell of public support for refocusing educational management on achieving concrete, practical outcomes is welcome, in truth we know painfully little about what specific learning outcomes are socially and economically useful, or how best to measure them. We even need better means to assess costs, as well as results, if "accountability" is going to be more than a hollow slogan.

We also need much better information about the scope and performance of the huge sector of our economy I call "the learning enterprise" to manage it effectively. Our current statistics about the formal education system of schools and colleges are remarkably shaky, simplistic, and misleading. And data about the even larger but less formal parts of the learning enterprise--not only corporate and government training programs, but such diffuse yet prodigious media as on-the-job learning, conferences, advertising, reading, television, counseling, sports, religion, voluntary associations, and "simple" conversation--are either scant or nonexistent. Such research as we have indicates that at least 90% and probably more than 98% of human learning takes place outside classrooms and other formal "instructional" settings. A key reason the learning enterprise is such an inefficient market is that both producers and consumers are so badly informed about how it operates and what it offers.

Another critical category for the Institute's research would be on the problems of implementation and diffusion of advanced learning technologies. As noted above, the extreme technological backwardness of American education stems less from a lack of fruitful technology than from a stifling web of institutional barriers to the widespread adoption and use of the valuable technology that already exists. We urgently need a much more subtle and thorough understanding of these barriers and how to eliminate them. We also need to learn a great deal about the kinds of organizational arrangements and incentives that can best accelerate the flexible adoption of learning technology.

In particular, any R&D plan must recognize that commercialization is a legitimate and in fact essential goal of the innovation process. No new technologies will be available to educators or students unless the tools can be sold for more than what they cost to produce. Grants, gifts, subsidies, and deep discounts will not lead to a technological revolution in education but only to another in a long series of dead ends. The Institute's entire program must aim at getting products to be marketed both competitively and profitably.

The proposed Institute would represent the concerns of the deliverers and practitioners of educational services. Broadly, the Institute would focus on supporting basic research (on one end of the innovation spectrum) and on removing institutional barriers to technological change (on the other end). This work should include commercialization of technology as one of its ultimate objectives.

However, even though some members of the Institute will and should be for-profit organizations, the R&D mission of the Institute explicitly should not include the development of particular commercial products. The simple reason is that everything we know about the history of the innovation process indicates that private, entrepreneurial organizations are the most prolific engines of successful product creation and diffusion.

Innovation and productivity are lacking in American education for basically the same reasons they are scarce in Soviet agriculture: absence of competitive, market forces.

If independent entrepreneurs are deemed too slow to introduce advanced learning products, an initiative parallel to the Institute might be considered to mobilize the producers and vendors of commercial educational products and services. This could be an "Educational Sematech"--a consortium linking vendors in a joint R&D venture. The consortium, like Sematech (a new collaboration of major U.S. semiconductor manufacturers), would pool R&D funds and staff contributed by member companies; it also could have a cooperative operating relationship with the Institute that might prove useful to accelerate the commercial application of the Institute's research. As a complement to the Institute's mission, the consortium would focus (in the center of the innovation process) on the development of marketable products.

From concept to action

While creating such a National Institute might at first seem to be a job for the federal government, I would argue that it is unlikely and probably even undesirable that this be a federal initiative.

First, closing the R&D gap between education and the rest of the economy means adding at least $4-8 billion to the current pool of educational R&D funds. While the federal government should contribute more than it currently does, it is simply not going to be able to provide anywhere near this kind of money.

The fact is education and training is mostly a state and local government function in the United States. It makes sense for the institutions that are spending the most money in the education sector to provide the largest share of R&D investment. About 80% of the college enrollment and 90% of the K-12 enrollment are in public institutions, chiefly state and local. Not only do state and local governments provide over 90% of the public funding of education in America, they both traditionally and constitutionally exercise most of the responsibility for education policy. Since local governments are constitutionally only creatures of the state, for the purposes of this proposal, the states are where the action needs to be.

The states are also by and large more flexible, adaptive, and innovative than the federal government. In fact, several state government

officials with whom I've discussed this proposal already have expressed considerable interest in taking action on it.

One or a few states setting aside at least 1% of their education budgets for a state R&D fund would form a sufficient base to start building a national program. As suggested earlier, a multi-state consortium would be a highly plausible way to organize the National Institute.

This is not to say that there is nothing the federal government can do to help close education's technology gap. Without getting into details here, the way the federal government now spends several hundred million dollars a year on educational research could be reorganized to achieve far more useful results. The President could use his "bully pulpit" to promote the action needed to bring the National Institute for Learning Technology to life. The federal government also could offer to add 10% to members' contributions to the Institute (a donation proportionate to the federal role in education).

Inevitably, the question will be asked: What is this initiative going to cost? The simplest and most accurate answer is: nothing.

The several billion dollar annual budget to be administered by the National Institute is not proposed as an **addition** to current education budgets but as a **reallocation** of existing funds to a more productive purpose. Because the explicit goal of the entire program is to greatly increase the productivity of the learning enterprise, the Institute's funding will be repaid many times over by the hundreds of billions of taxpayer and consumer dollars that will be saved as a result of this investment. The real cost associated with education's technology gap is the huge cost of continuing to do nothing to close it.

Another inevitable question is: Will the education community buy this proposal?

That remains to be seen. But professional educators should support it if they consider where the success of this initiative would lead for them: to a learning enterprise with a much greater capital/labor ratio, employing a smaller number of highly skilled, highly productive, highly compensated, and more autonomous professionals employing an array of extremely powerful technical tools to provide better services to more people at lower cost.

In reality, many educators will not and, in fact, should not support this R&D proposal unless it is linked to the rest of the essential agenda for restructuring American education.

The key elements of that agenda are being defined by such forward-looking leaders as David Kearns, chairman of Xerox Corp., Albert Shanker, president of the American Federation of Teachers, Joe Fernandez, Miami's school superintendent, and Minnesota Governor Rudi Perpich.

The emerging agenda for educational *perestroika* includes: Empower educators to control the resources and operations of their own schools--what's called "school based management." Give families and students the freedom to choose among public schools. Link funding to enrollment so that schools have to compete for revenues by attracting consumers.

For this kind of market-based system to work, we need realistic accounting for the results we want education to achieve, and meaningful incentives for their attainment. This means, first, replacing current tests with valid measures of the knowledge and skills students really need for either employment or higher education.

The important incentives for students, as Shanker has argued, should be that acceptance in a job or a college would depend on the documented achievement of the competencies required for entry to either. For school staff, in addition to the incentives inherent in a market system, Shanker proposes to goad their commitment to restructuring by arranging to award a sizable bonus--perhaps $15,000 to $30,000 per person--every five years or so to the individual schools (in restructured districts) that achieve the greatest improvement in measured outcomes.

While the latter restructuring measures focus on public schools, the same basic agenda applies to higher education and training programs: entrepreneurial management, choice, competition, competency-based instruction and employment, and rewards for performance. Adding the kind of R&D initiative proposed here to close the technology gap makes this a complete prescription for replacing an archaic education system with a 21st-century learning enterprise.

[1]The importance of education and training to the modern economy is by now widely appreciated. For details see William Johnston and Arnold Packer, *Workforce 2000: Work and Workers for the 21st Century* (Indianapolis: Hudson Institute, 1987) and Lewis J. Perelman, *The Learning Enterprise: Adult Learning, Human Capital, and Economic Development* (Washington, D.C.: Council of State Planning Agencies, 1984).

[2]For example, see David Kearns and Denis Doyle, *Winning the Brain Race: A Bold Plan to Make Our Schools Competitive* (San Francisco: ICS Press, 1988).

[3]Henry Kelly, *Technology and the American Economic Transition: Choices for the Future* (Washington, D.C.: Office of Technology Assessment, 1988).

[4]Ithiel de Sola Pool, "Tracking the Flow of Information," *Science*, 12 August 1983.

[5]At the bottom of this group of 33 companies was a firm that invested only $790 per employee in R&D last year. The composite (a weighted average) R&D spending per worker of the surveyed companies in this business was $18,428.

[6]The magazine surveyed companies reporting sales of at least $35 million and R&D expenses at least equal to $1 million or 1% of sales So small firms or those making little investment in innovation are not included. But most academic enrollment is in school districts and public universities whose budgets would make them big businesses compared to companies on the magazine's list. And the point of this paper is that educational organizations should be among the leaders in innovation. So the "Scoreboard" is a relevant yardstick of education's R&D gap.

[7]Linda G. Roberts, *Power On! New Tools for Teaching and Learning* (Washington, D.C.: Office of Technology Assessment, 1988).

[8]The OTA Report (Roberts, 1988) estimated only one computer for every 30 students.

[9]The program was terminated this year by a new district superintendent.

[10]For example, see "Computers in School: A Loser? Or a Lost Opportunity?" *Business Week*, 17 July 1989," and "Computers Make Slow Progress in Class," *Science*, 26 May 1989.

[11]Douglas Ellson, "Improving Technology in Teaching," *Phi Delta Kappan*, October 1986.

[12]Since the breakup of the telephone monopoly, Bellcore (Bell Communications Research) has been jointly supported by the Regional Bell Operating Companies. Bell Labs is now exclusively the R&D center for the AT&T corporation.

[13]Roughly four times as many people are employed in elementary and secondary education as in higher education.

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